PSYCHOLOGY 305
COGNITIVE PROCESSES

Cognitive Control and Prefrontal Cortex (Chap12, p507-520;553~555)

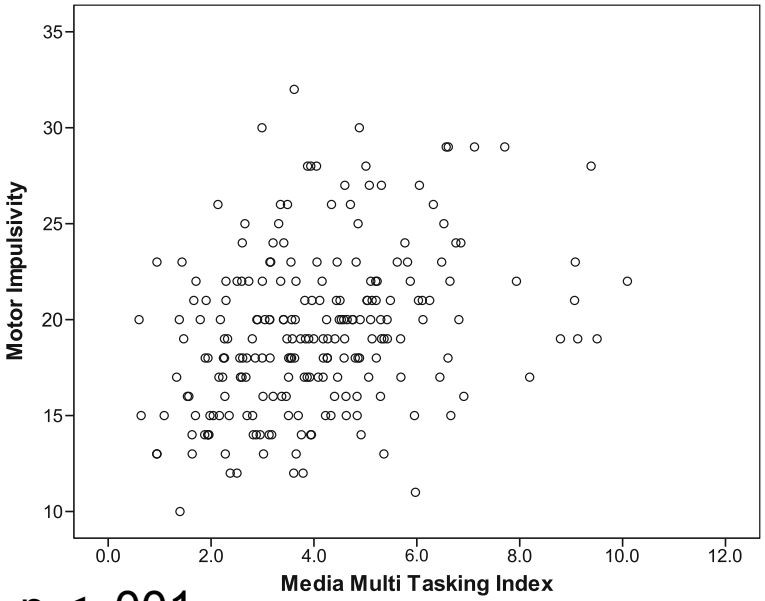
1. Intro
2. PFC & Short-term memory/working memory.
3. Top-down control.
4. Goal oriented behavior.
5. Task-monitoring/conflict monitoring.

Media Multitasking

- Juggling among multiple tasks rather than focusing on one task for a long period
- Are Heavy/Chronicle media multitaskers (HMM) better at multitasking because of their habit/expertise?

Media Multitasking

- HMMs show lower in fluid intelligence than LMMs (Minear et al., 2013)
- Media multitasking index correlates with impulsiveness (Minear et al., 2013;Sanbonmatsu et al., 2013)
- Low cognitive control (Sanbonmatsu et al., 2013)

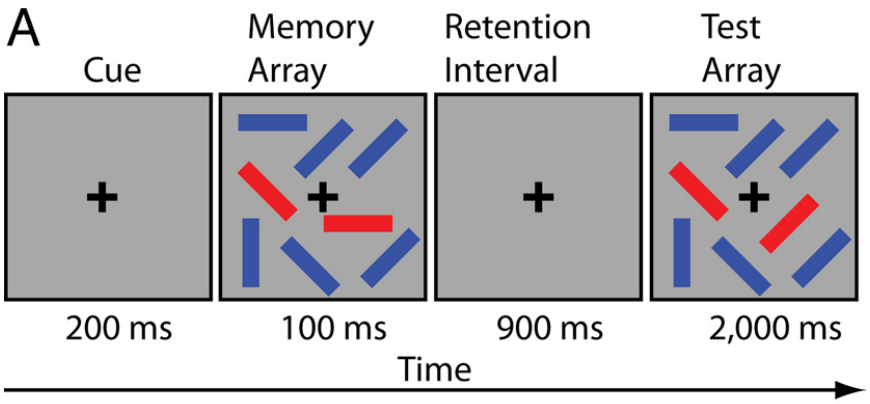


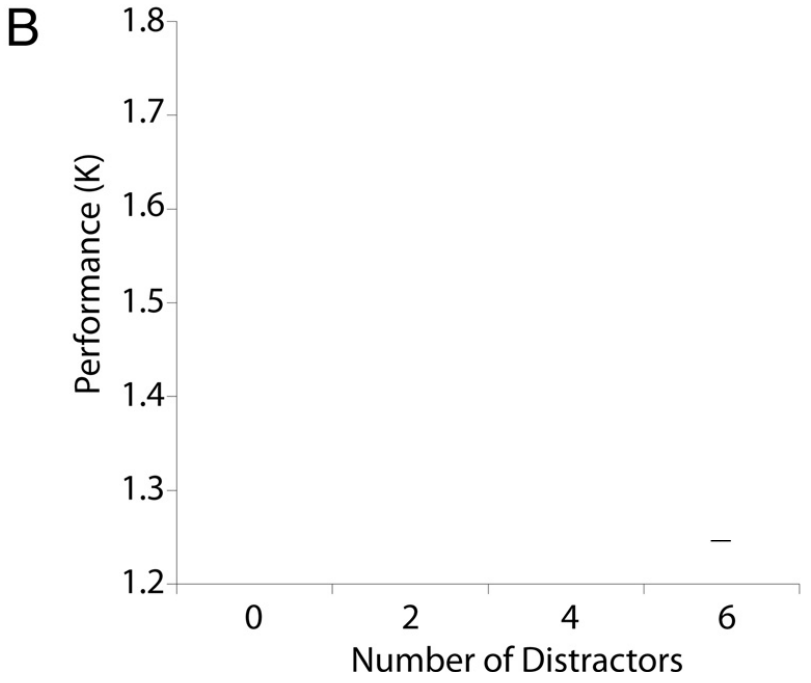
motor impulsivity, r = .33, p < .001

Filtering Environmental Distractions

- HMMs were linearly negatively affected by distractors
- LMMs were unaffected by distractors
- LMMs have the ability to successfully filter out irrelevant stimuli

LMMs better at cognitive control, and thus intentionally focusing on a single task in the face of distractions



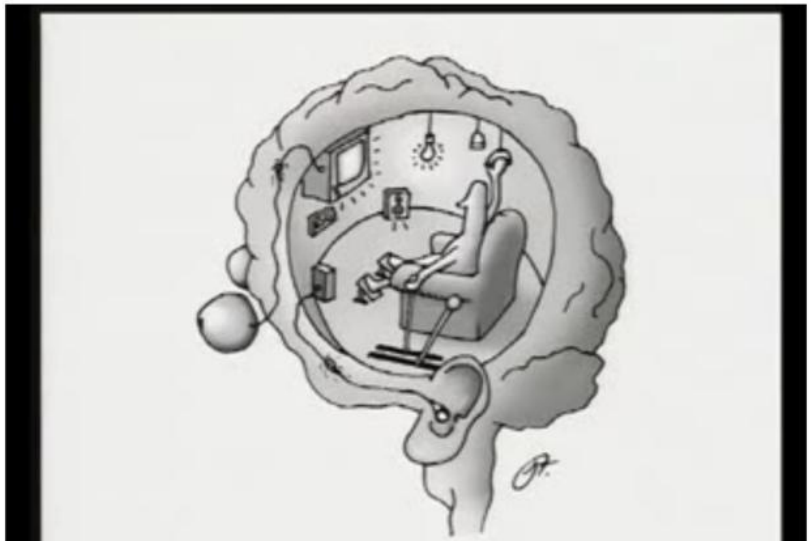


What is cognitive control?

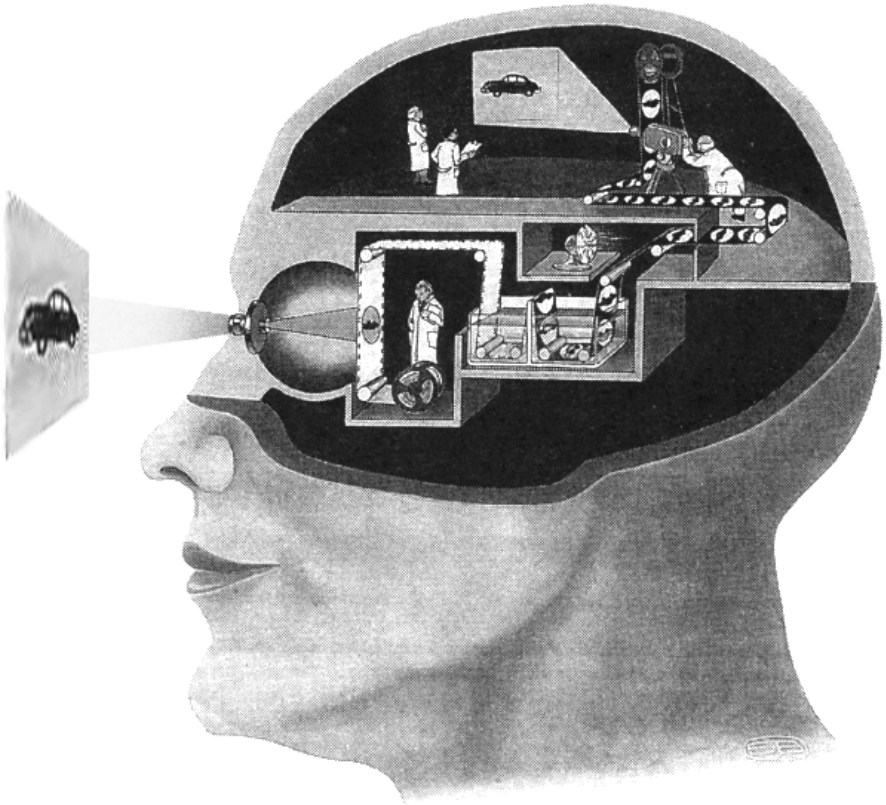
- The concept of cognitive control is our "executive" control of other brain systems.
- Idea is that you need a region that handles "executive" processing of other brain regions.

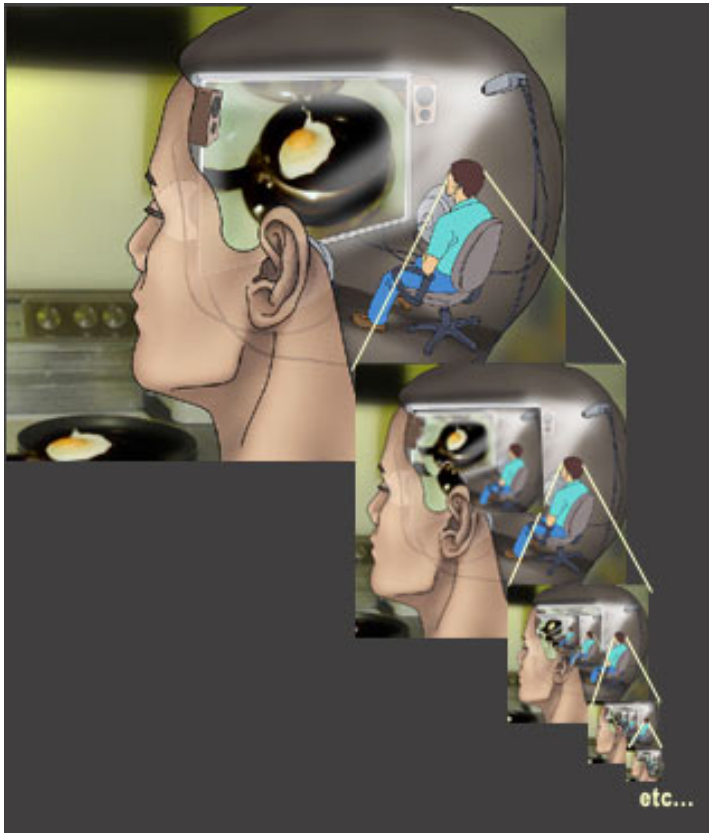
Think, pair, share

- A homunculus is the idea there is a small part of your brain that gives out orders to the rest of the brain.
- Think of it like a small person inside you that is ‘at the wheel’, controlling what you do.
- What are potential issues with this idea?



Potential issues with idea of central executive

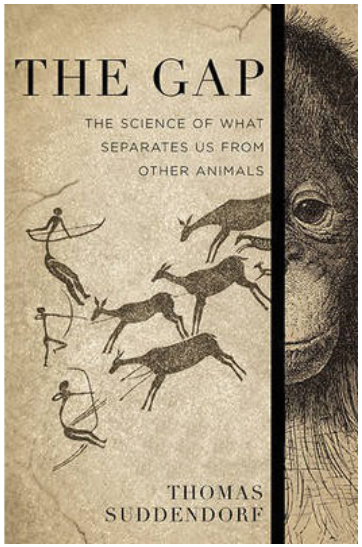




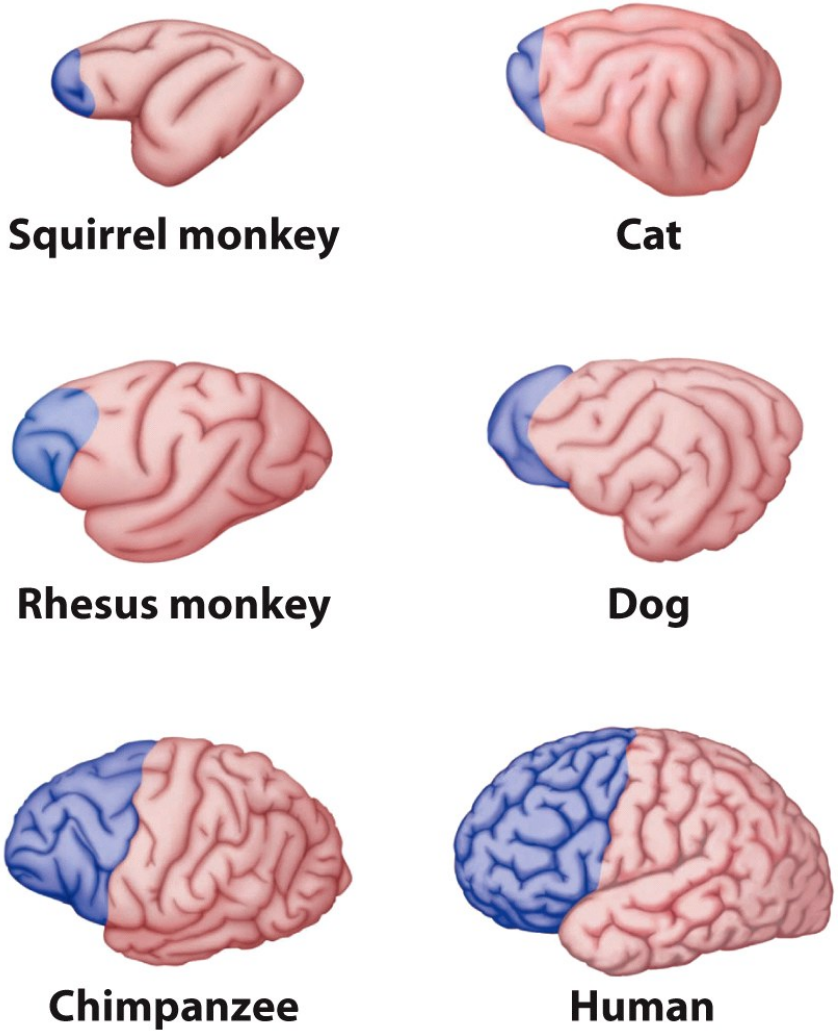
- Who controls cognitive control? An infinite regress problem
- Toward a more nuanced view of cognitive control...

Frontal cortex and cognitive control

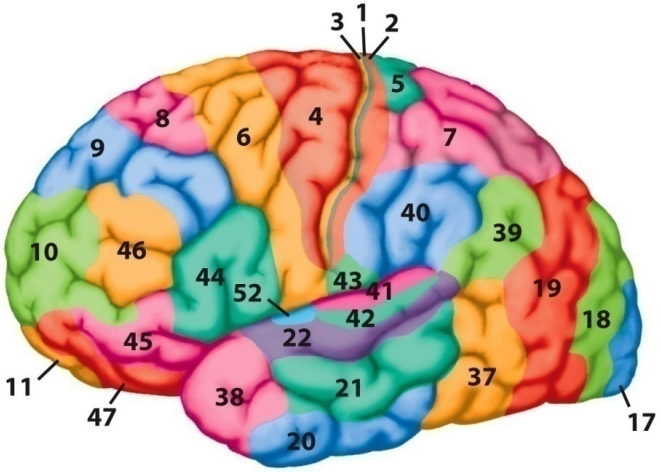
- Human frontal cortex has massive bi-directional connections to most cortical and subcortical areas.

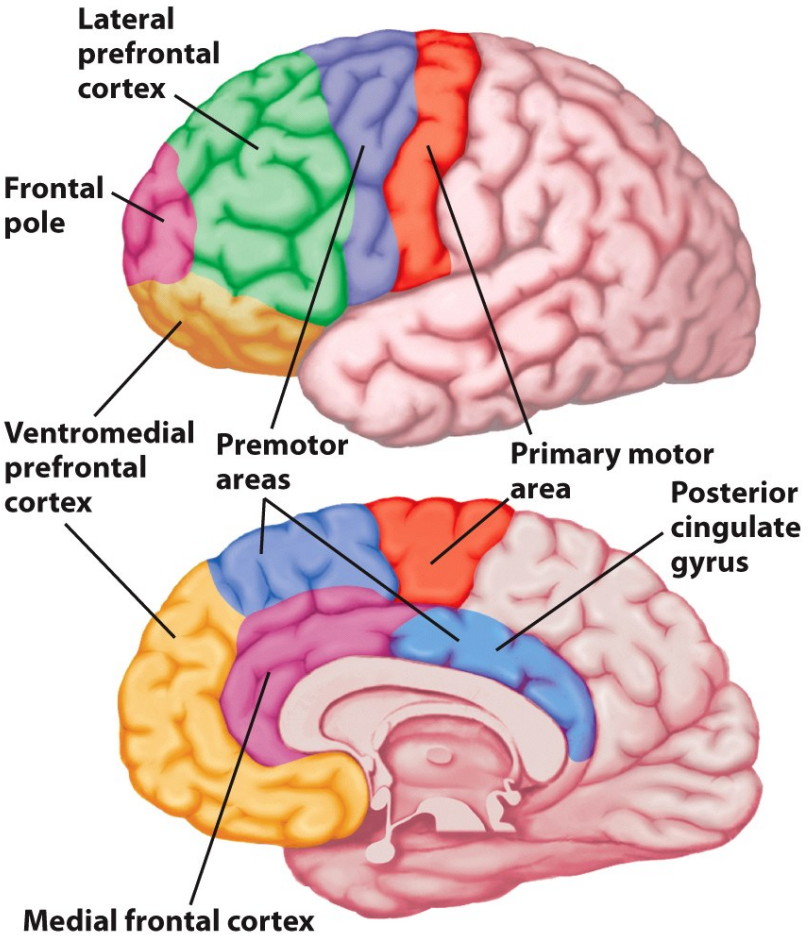


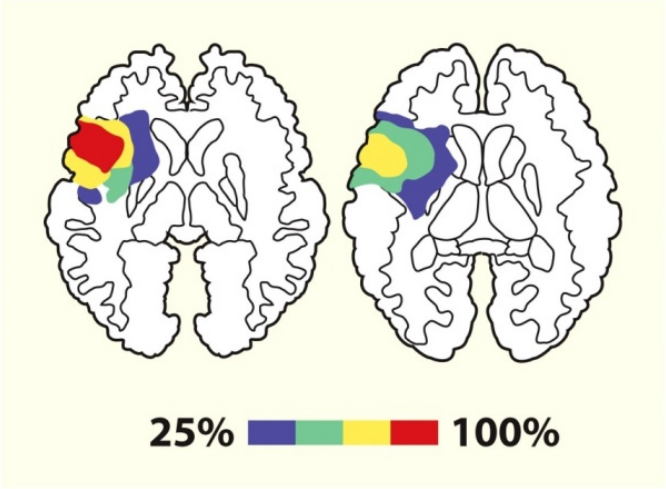
The Gap: The Science of What Separates Us from Other Animals by Thomas Suddendorf



Lateral prefrontal cortex, BA 45, 46







Cognitive control and PFC?

- Several aspects involved:
  - short-term memory (working memory)
  - goal-oriented behavior
  - filtering of (ir)relevant information
  - response inhibition and selection
  - top-down control
  - task/error monitoring

Discussion of what the frontal cortex does

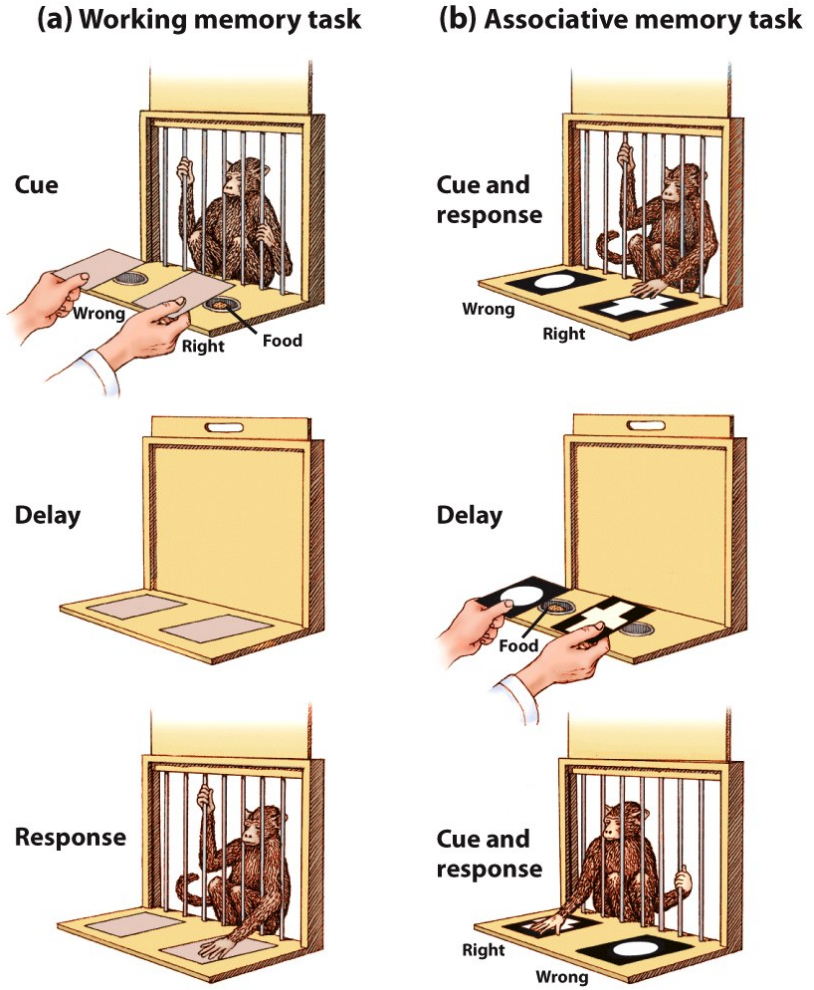
- MMI and distractor inhibition in the case study at the beginning
- Short-term memory/working memory.
- Top-down control
- Goal oriented behavior.
- Task-monitoring/conflict monitoring.

Working memory

- Where past knowledge or recent information can influence current behavior.
- Mechanism needs to:
  - Reactivate stored information.
  - Keep information active.

Lateral prefrontal cortex and working memory

- Delayed-response task
  - WM task: hold the location of the reward in mind. Must maintain location of reward.
  - Associative memory task: build an association between reward location and cue. Do not need to maintain an active memory of reward location. Use associative rule to choose reward.

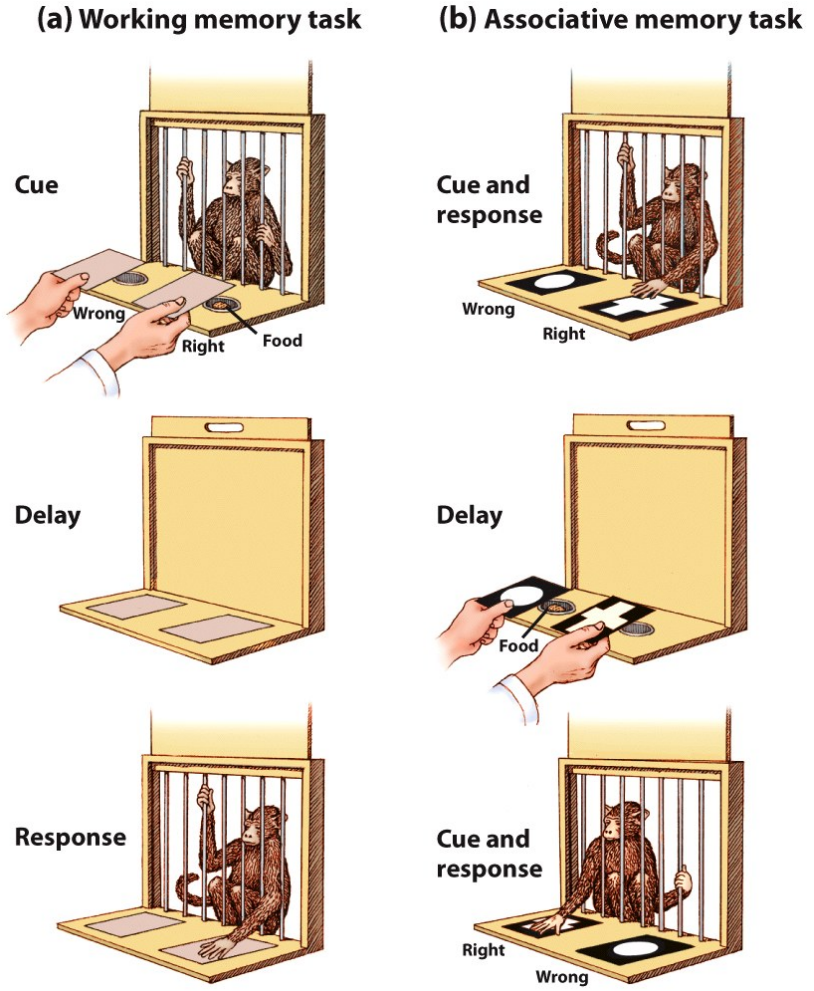


PSYC305: Cognitive Control

- Continue cognitive control
  - New slides on class website

Lateral prefrontal cortex and working memory

- Delayed-response task
  - WM task:
    - Monkeys with dorsolateral prefrontal lesions (Brodmann's areas 46,9) impaired at WM task.
    - "out of sight, out of mind"
- Associative memory task
  - Long-term memory and cue recognition:
    - Prefrontal lesion monkeys ok
    - Monkeys with hippocampal lesions had trouble with similar task.

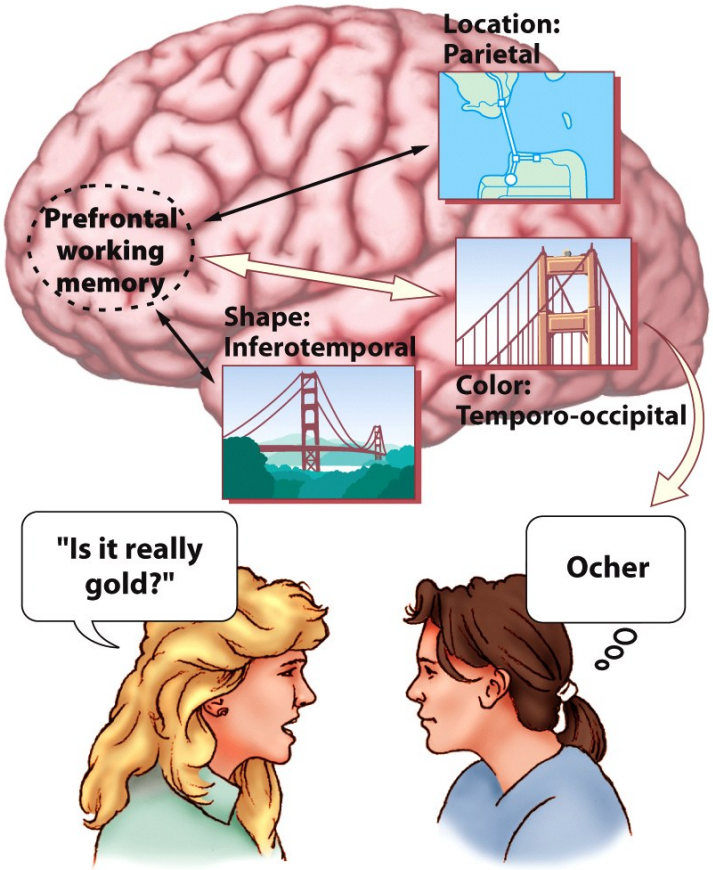


Discussion of what the frontal cortex does

- Short-term memory/working memory.
- Top-down control.
- Goal oriented behavior.
- Task-monitoring/conflict monitoring.

Prefrontal cortex and information selection

- Dynamic filtering hypothesis
  - PFC *selects* and maintains task-relevant information in working memory
  - *Inhibits* task-irrelevant information
  - Works with attention to modulate processing in relevant sensory areas.

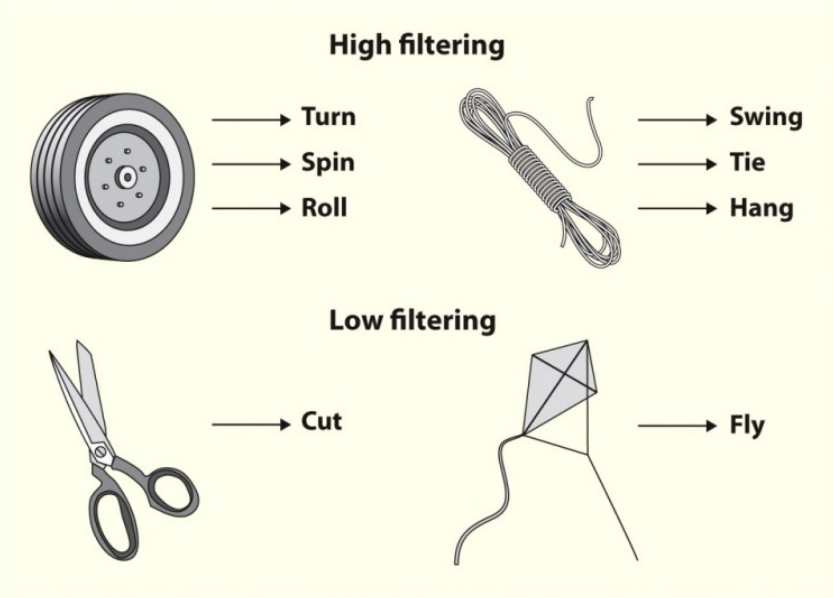


Think, pair, share

- How would you investigate the dynamic filtering hypothesis?
  - PFC *selects* and maintains task-relevant information in working memory
  - *Inhibits* task-irrelevant information
  - Works with attention to modulate processing in relevant sensory areas.

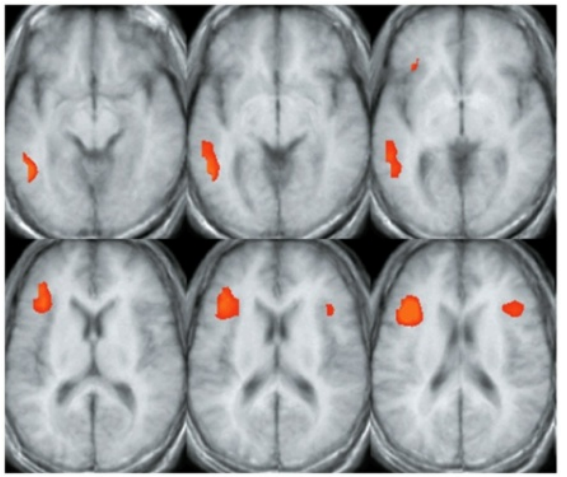
Evidence for dynamic filtering: selection

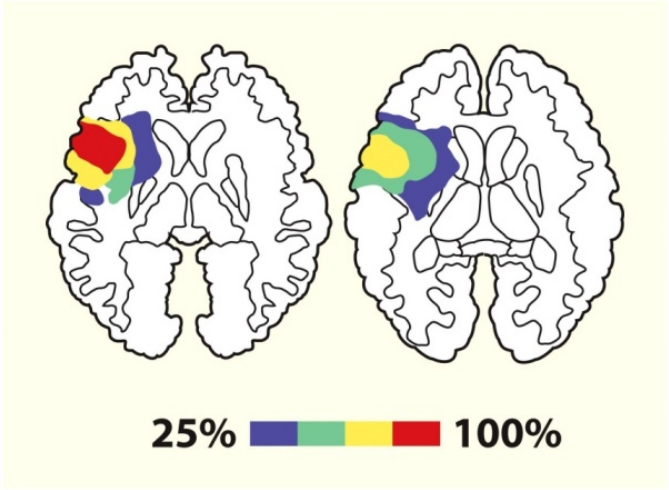
- High filtering
  - Select one of many responses
  - Lots of competition
- Low filtering
  - Little competition



Evidence for Dynamic Filtering: selection

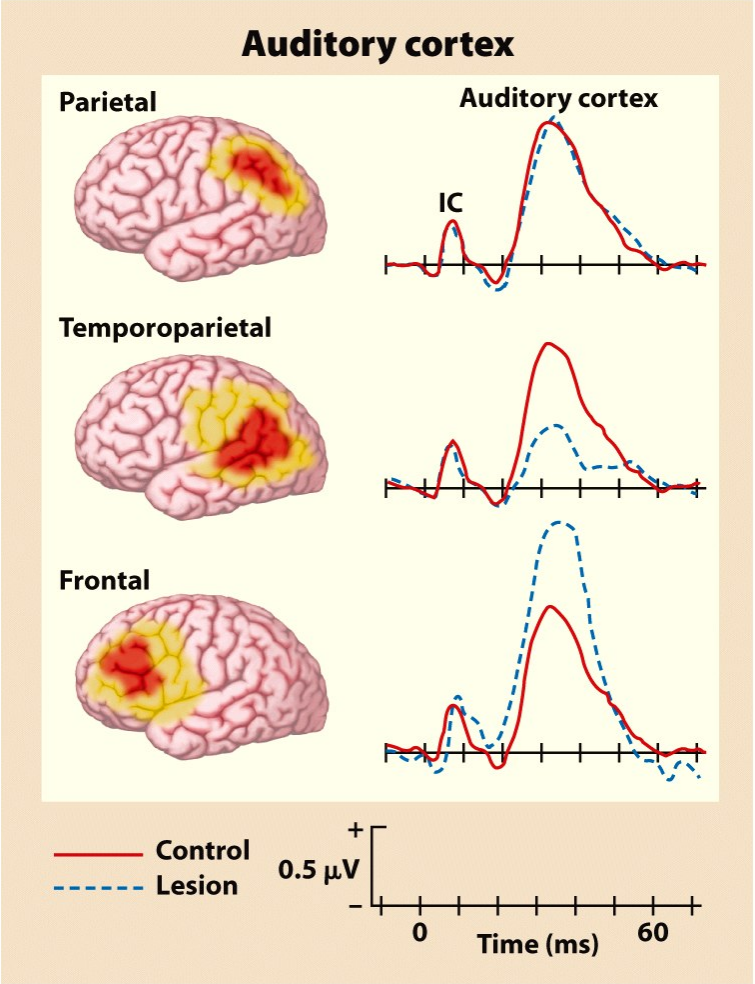
- High compared to low filtering conditions.
  - Prefrontal cortex and temporal lobe (semantic storage) more activated in fMRI.
  - Prefrontal patients failed to choose any response.
    - Not problem with semantics.
    - Not an erroneous choice.





Inhibition

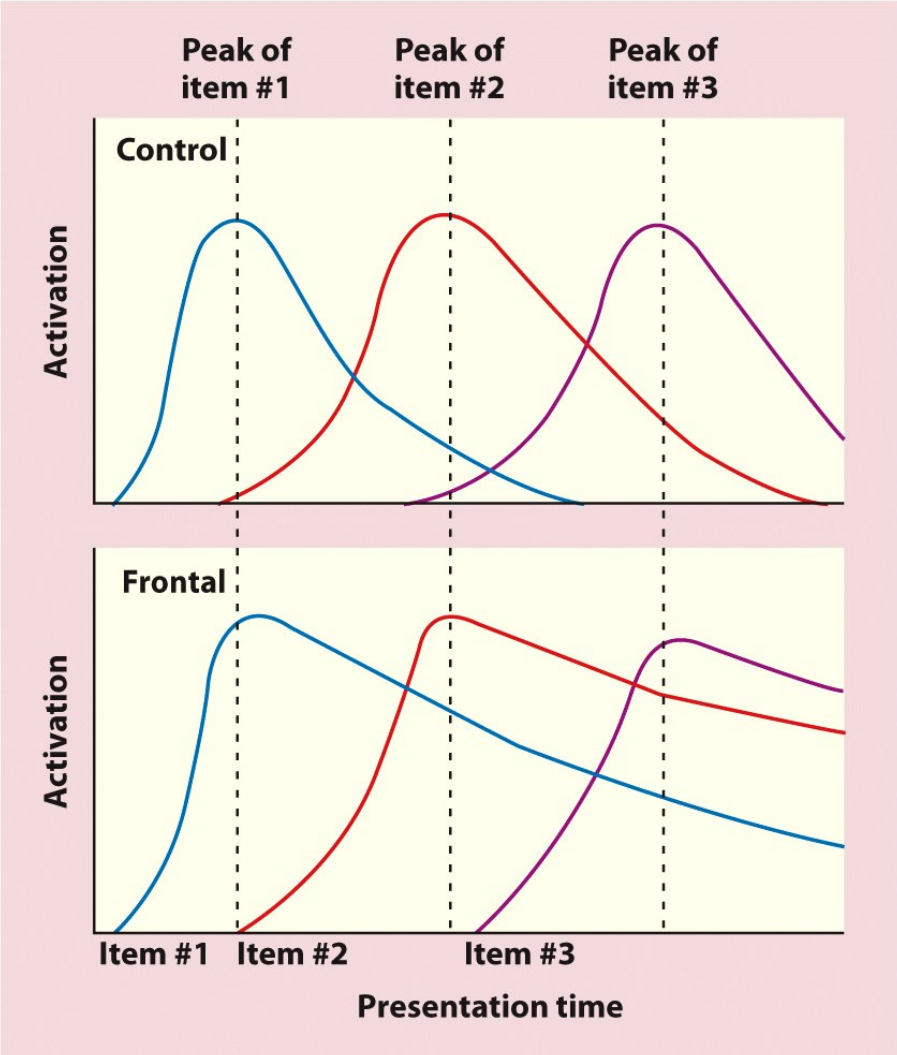
- ‘Ignore the auditory clicks’
- Frontal lobe patients fail to inhibit irrelevant sensory stimuli



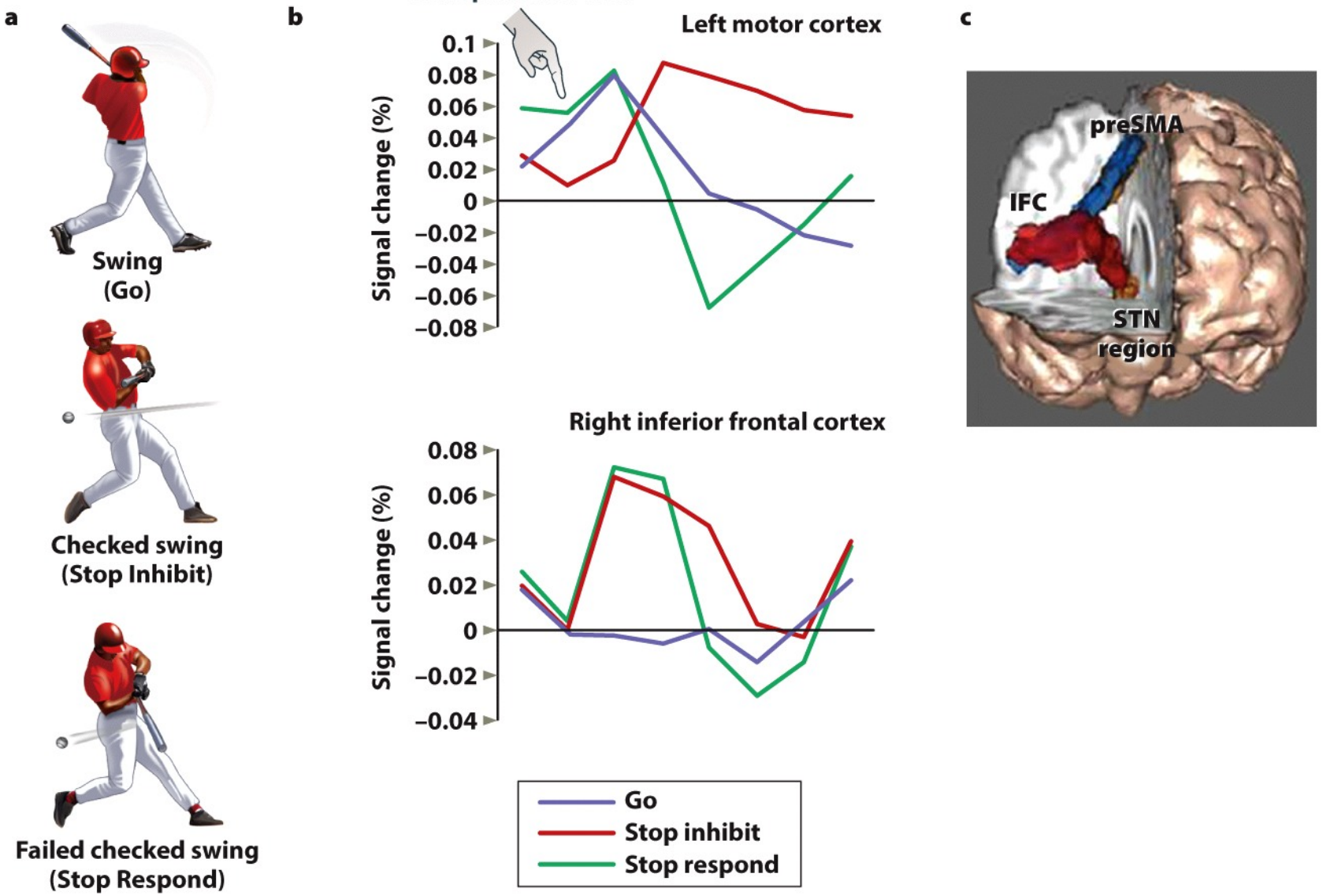
Inhibition

- Frontal lobe patients fail to inhibit irrelevant sensory stimuli

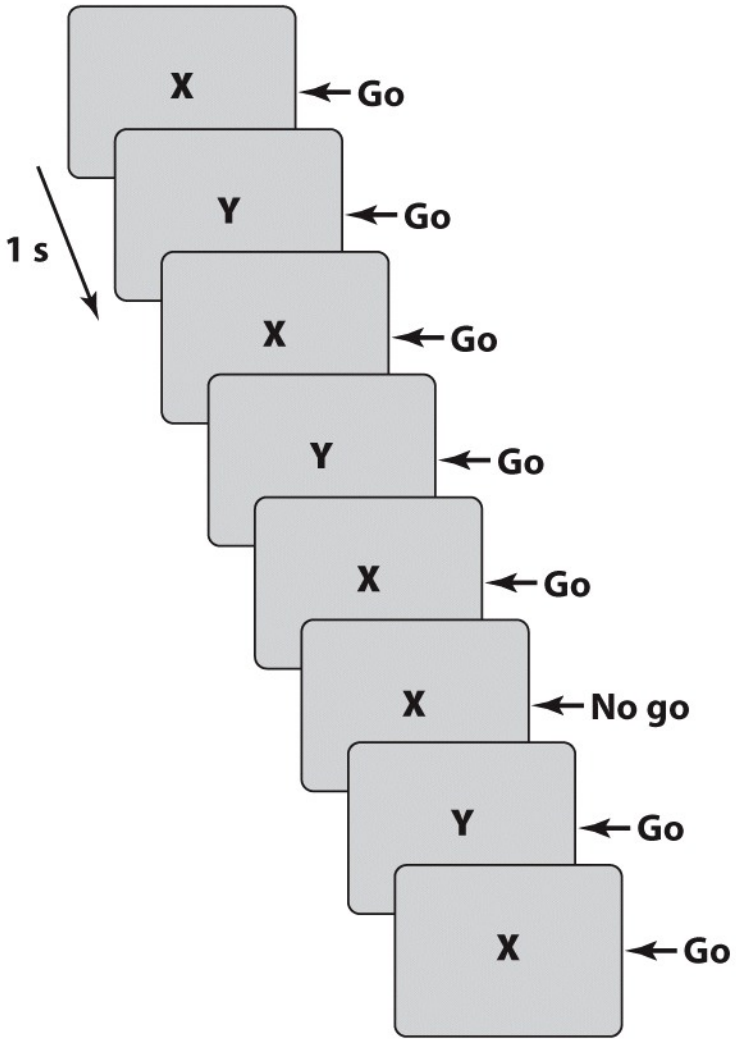
- Lack of inhibition could account for problems in temporal memory, perseverations, loss of signal.

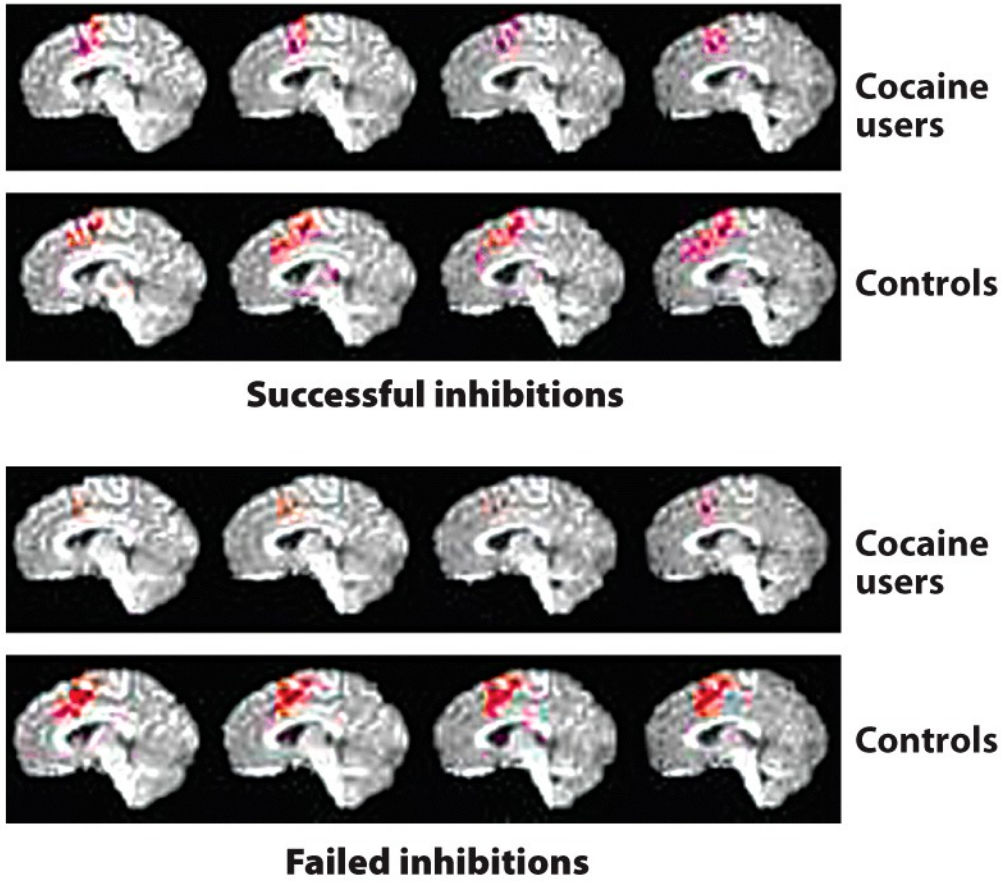


Role of the right inferior prefrontal gyrus in inhibitory control

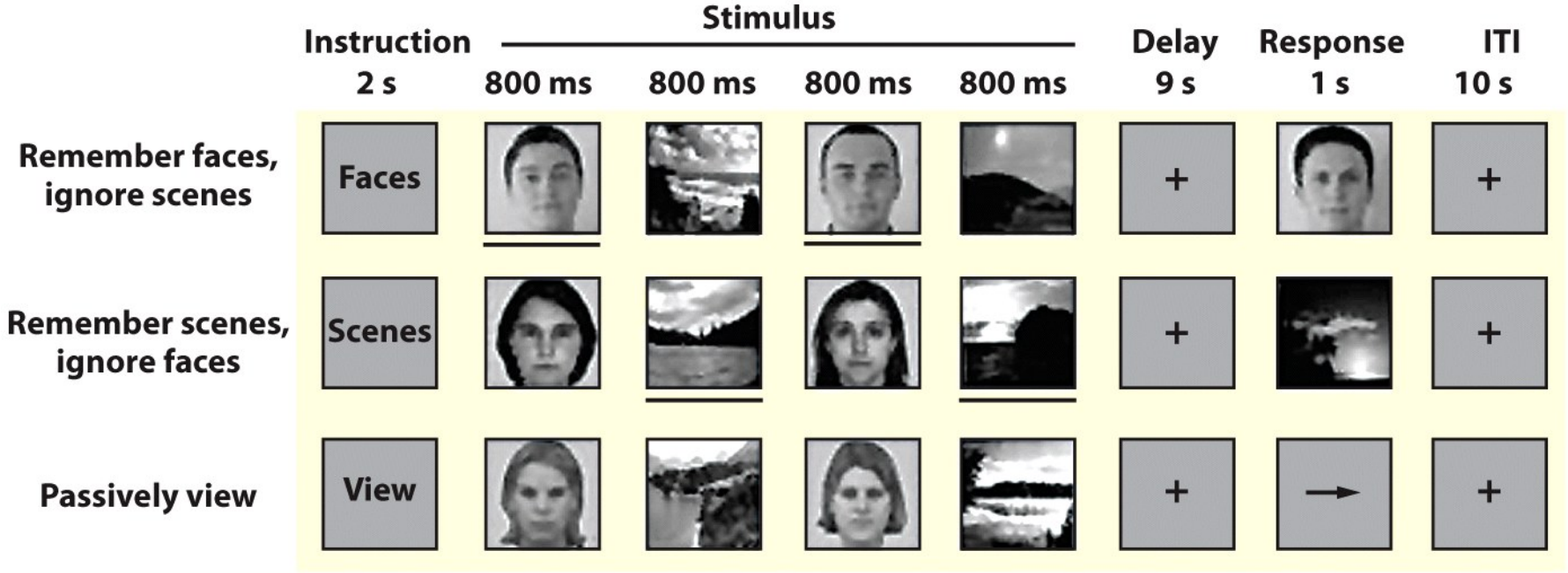


Reduced inhibitory control in chronic cocaine users





PFC may also play roles in modulating “lower” brain regions



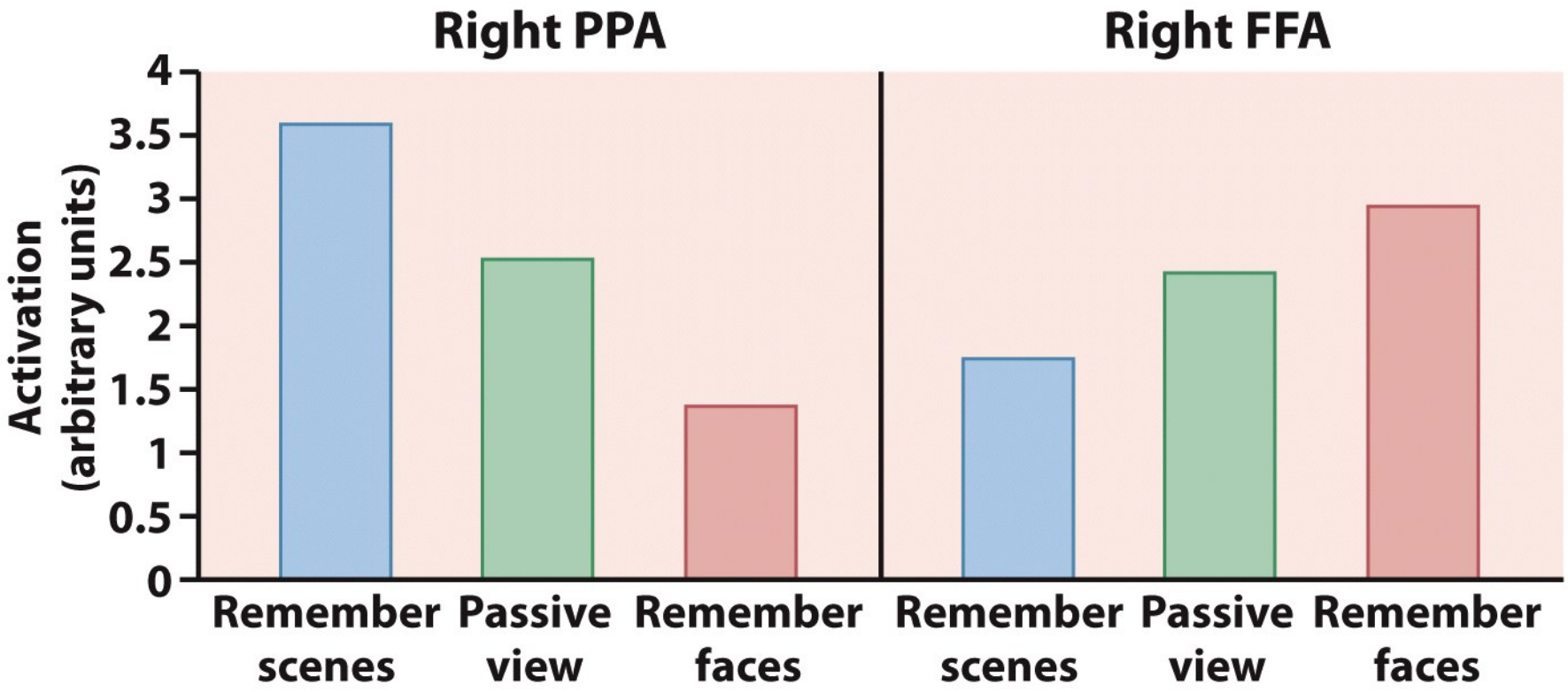
- In experiment, subjects see both scenes and faces.
- However, after delay, either tested on face (thus must ignore scene) or tested on scene (thus must ignore face).
- Control is passive viewing of both.

D’Esposito

“Lower” brain regions

- FFA: **F**usiform **F**ace Area, shows activation during fMRI for faces in humans.
- PPA: **P**arahippocampal **P**lace **A**rea, shows activation during fMRI for scenes in humans.

Results



- Greatest activation of PPA when remember scenes vs. passive view,
- Greatest activation of FFA when remember faces vs. passive view. Least activation when task they are not involved in.

- **Top down control can affect ‘lower’ brain regions involved in perception**

Discussion of what the frontal cortex does

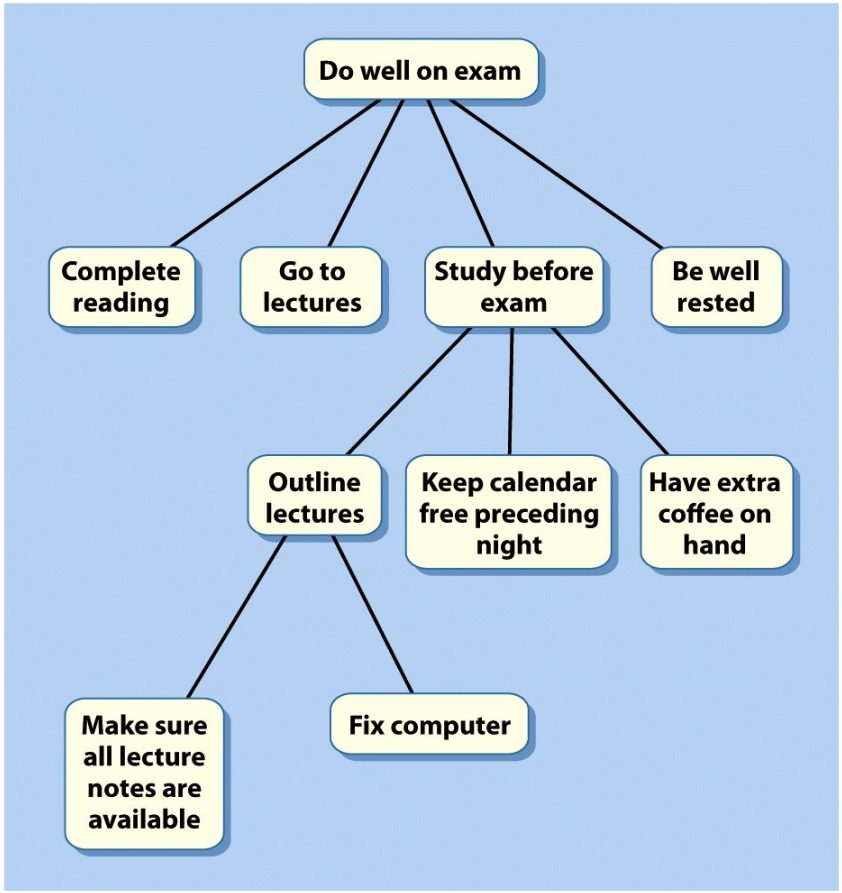
- Short-term memory/working memory.
- Top-down control.
- Goal oriented behavior.
- Task-monitoring/conflict monitoring.

Goal-oriented behavior

- Hallmark of well studied patient with lesion to PFC, W.R. (lawyer that looses ambition).
  - Loss of:
    - Goal-oriented behavior.
    - Cognitive control.
    - Long-term purposeful behavior.
    - Flexible use of knowledge to guide behavior based on task demands.
  - Behaviorally stimulus-driven.
- Consider now in terms of goal selection.
  - The idea of planning and selecting an action.

Goal-oriented behaviors

- Good performance involves hierarchical goal and plan development.
  - Subgoals
  - Flexibility, adaptability
  - Linking past outcomes with current subgoals
- Relies on combination of prefrontal functions.



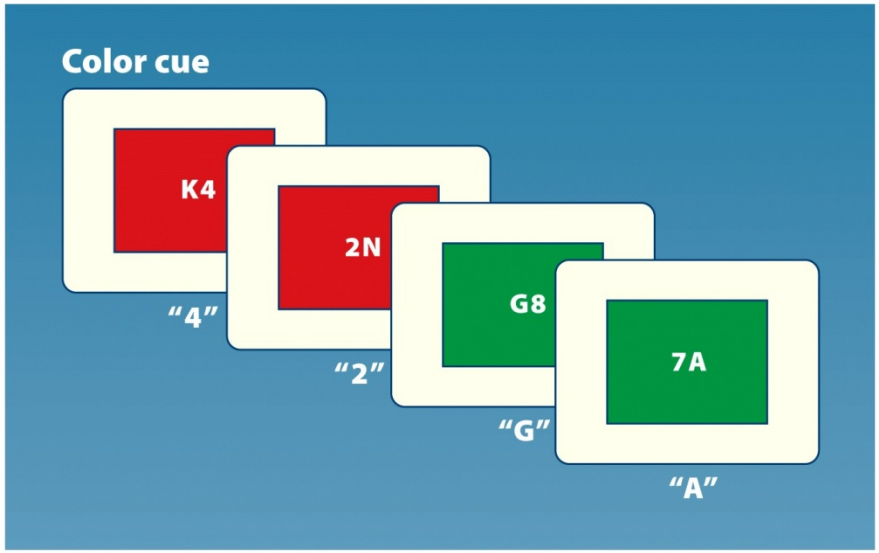
Goal oriented behavior: Wisconsin Card Sorting Task

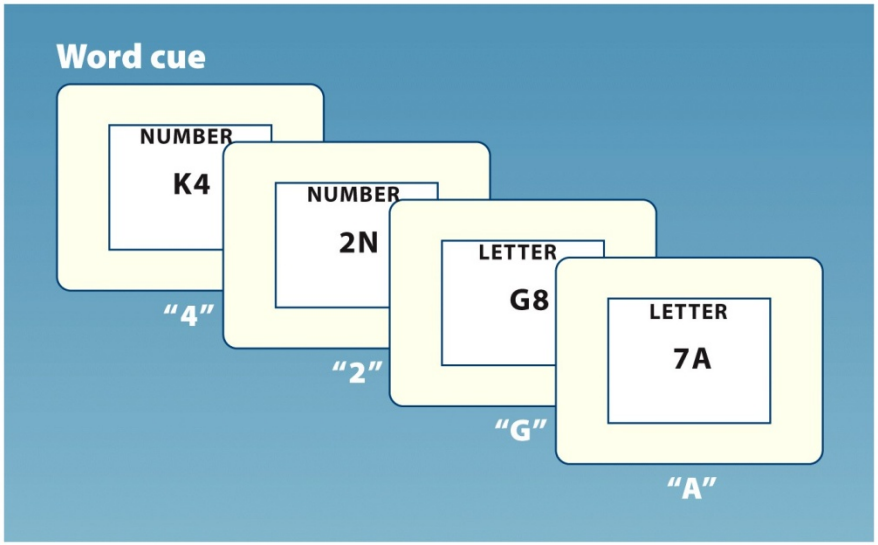
- Sort cards according to a rule.
- Subject must “discover” rule by trial and error.
- Rule may change at any time.
- Frontal lobe patients:
  - Perseverate (apply old rule after new rule has been instantiated).
    - Trouble task-switching
  - Have difficulty keeping track of previous outcomes.
    - Selection or inhibition based on temporal order

Task-switching

- Sub-goals need to be adjusted with task demands.
  - Color cue requires reference back to memory.
  - Word cue does not require memory for current task goal.

Trial # 3: RT_{switch} Trial # 2 & 4: $Rt_{no\text{-}switch}$

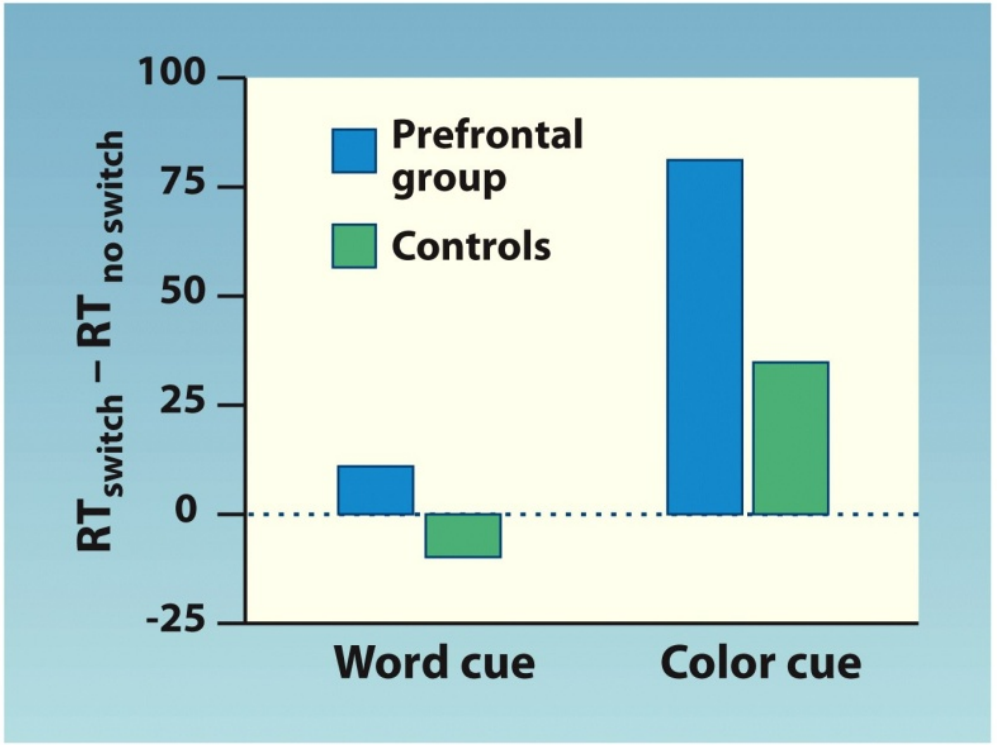




Red: number
Green: letter

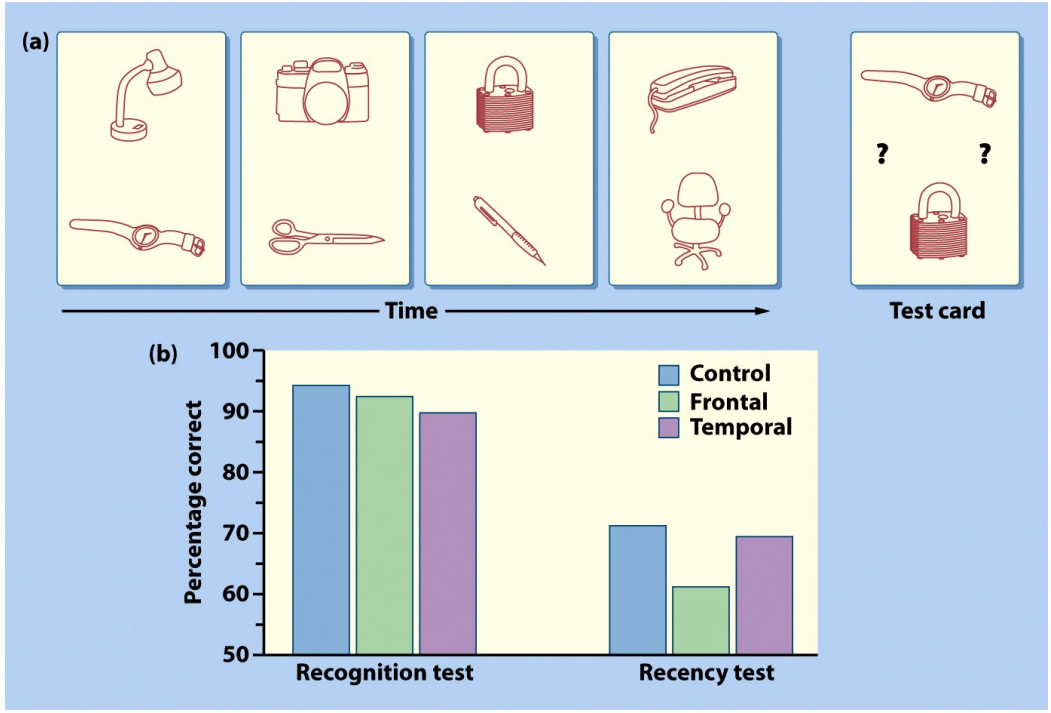
Task-switching

- *Switching cost:* slower response associated with trials where goal changes.
- Prefrontal patients worst with color cue
  - When goal needs to be retrieved from long-term memory and brought into working memory.



Prefrontal cortex and information selection over time

- Temporal structure of memory
  - Inability to keep track of the order in which things happened or should happen.
- Source memory
  - Where a specific fact was learned.



Recognition test – "Was this one of the studied items?"

Recency test – "Which one came most recently?"

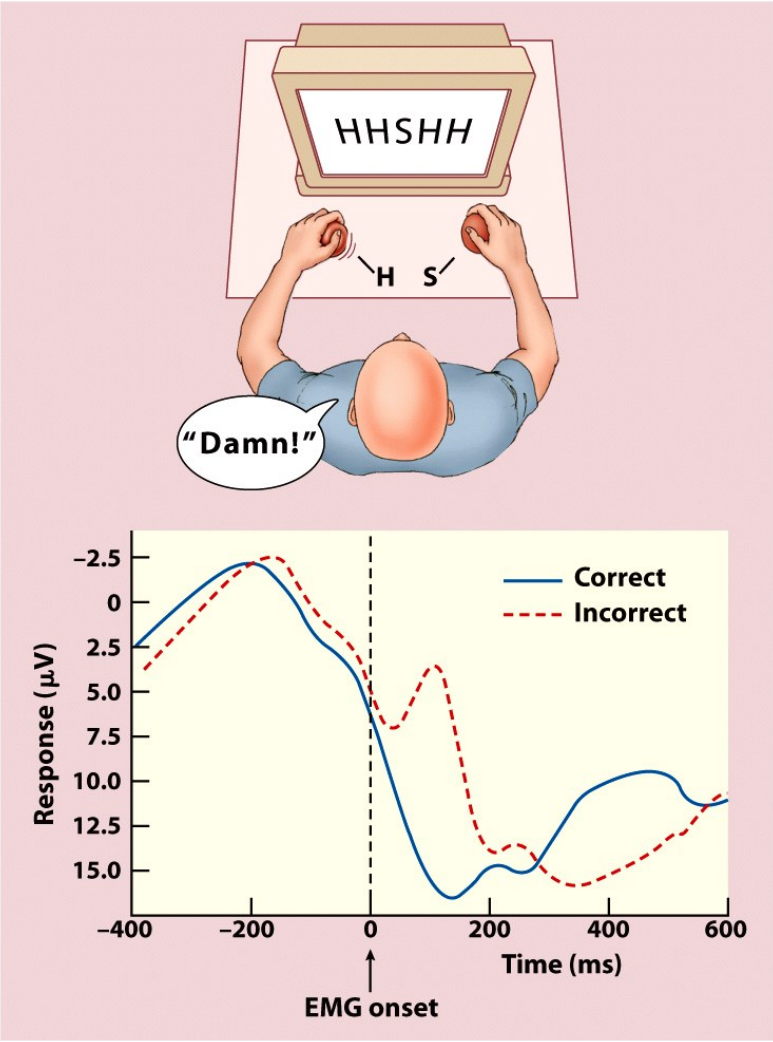
Discussion of what the frontal cortex does

- Short-term memory/working memory.
- Top-down control.
- Goal oriented behavior.
- Task-monitoring/conflict monitoring.

In many instances, need to monitor "errors" or "conflicts" during a task

- Medial frontal cortex (anterior cingulate, ACC) often activated in these tasks.

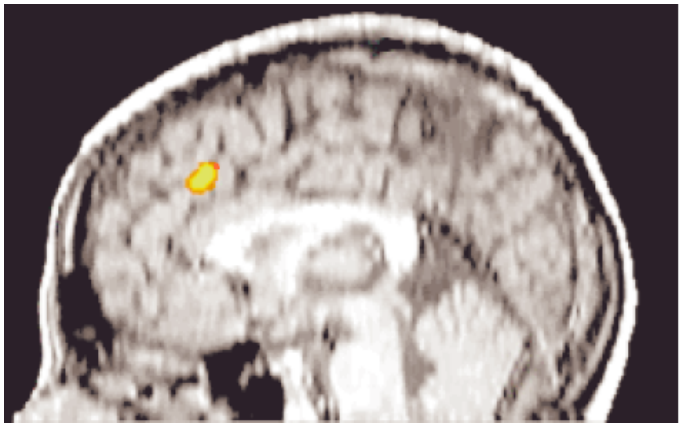
Error monitoring

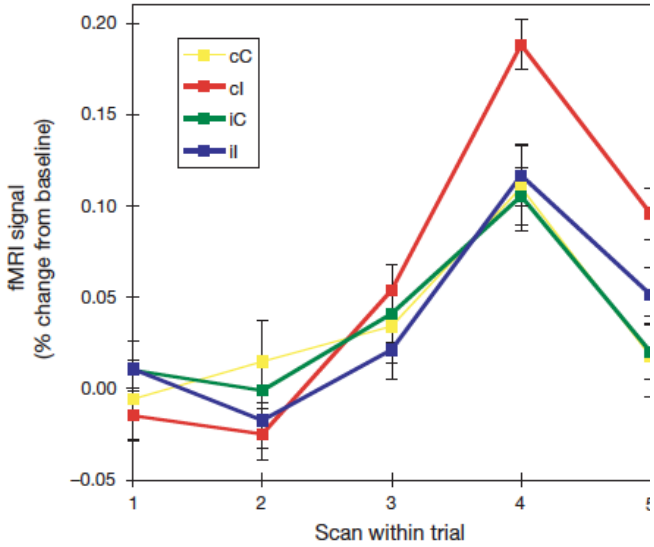


- Subjects hit one button for S another for H.
- Task is harder when distracting letter flank.
- ERP scalp response (Error-related negativity, ERN) is greater when subjects give incorrect response.
- ERN may originate from ACC within MFC

Conflict monitoring: Modified version of task uses arrows instead as flankers with fMRI

- Compatible trials:
- >>>>>> > >>>>>>>>>>
- Incompatible trials:
- <><><> < ><><><>>>>>
- Highest conflict trials will be ones in which compatible precede incompatible (cI trials).
  - Highest activation during cI trials.





Suggests activation in ACC may relate to monitoring of conflict.

Botvinick et al., 1999, Nature

summary

Essentials

- Concept of cognitive control.
- Anatomy of relevant frontal areas of the brain (lateral prefrontal cortex, medial frontal cortex, …).
- Role of prefrontal cortex in short-term/working memory
- Top down control by PFC of brain regions involved in face/scene processing.
- PFC and role in goal-oriented behavior/task-switching.
- Medial frontal cortex and error detection and task monitoring.